

## EFFECT OF NEGATIVE ION ATMOSPHERIC LOADING ON COGNITIVE PERFORMANCE IN HUMAN VOLUNTEERS

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*Negative ion atmospheric loading has been reported to affect a range of psychological functions, from alertness to circadian rhythms, and has been suggested to benefit a variety of medical conditions, from allergies to migraine. In a double-blind study planned to assess the effect of negative ions on cognitive performance in human volunteers, 65 female graduate course students were randomized into ionized atmosphere (n = 34) and control (n = 31) groups. The following cognitive tasks were administered : Digit Symbol Substitution Test, Addition Test, Visual Memory (Complex Figure) Test, Verbal Memory (Complex Passage) Test, Ideational Fluency Test and Clerical Speed and Accuracy test. On all but the last two tests, the negative ion group performed significantly better (to a 15-40% extent) than controls. It is concluded that negative ionization of the atmosphere by artificial means may be of benefit in certain common, practical situation in which depletion of these ions occurs.*

The normal atmosphere contains neutral molecules, positive ions and negative ions. Such atmosphere ionization is produced naturally chiefly by solar radiation and by naturally-occurring (soil and atmosphere) terrestrial radiation, but to a small extent also by natural phenomena such as thunderstorms, snowstorms, waterfalls, water spray on the shoreline, winds etc. In normal country air, the ratio of negative to positive ion is about 4:5 in city air, this ratio is reduced to 1:2, further reduction may occur in certain situations.

On a widespread scale, relative depletion of negative ions (due to actual depletion or to positive ion surfeit) may result from atmospheric pollution; in small pockets, relative depletion of negative ions may be due to air-conditioning, television or computer screens, central heating, machinery, artificial fibre material (clothing, carpets, curtains etc.), cigarette smoke and so on.

The balance between negative and positive ions has been suggested to be critical for ideal physical and psychological health, with adequacy of negative ions being the purveyor of

benefit - consider, for example, the 'freshness' of the air near the waterfall, at the shoreline, or after a thunderstorm (in which situations negative ions predominate), and the mood disturbance and psychosomatic complaints induced by dry winds such as the mistral in France, the sharav in the near East, the zonda in Argentina, the chinook of the Rocky Mountains, and the foehn elsewhere (all of which are associated with a positive ion surfeit).

Although air ions were described towards the end of the 19th century, serious scientific investigations with hard data and results did not occur until the 1930s. Since then, much medical information has become available.

The history of air ions, their physical generation, properties and psychobiological effects are reviewed in greater detail elsewhere (Krueger and Read, 1976; King, 1979).

While air filters eliminate dust particles > 5 microns in diameter, ionizers which generate negative ions precipitate particles > 0.5 microns in diameter (Nagy, 1960). An

unpublished report (dated 5-3-1990) from the Materials Technology Division of the Central Power Research Institute (Bangalore) documents 70-80% reduction in ambient suspended particulate matter 24 hours after introduction of an ionizer; this effect was maintained over a week of assessments.

Reduction in ambient pollutants could reduce the incidence of allergic disorders such as hay fever, bronchial asthma etc., as had indeed been observed with use of ionizers (Chaitow, 1990). Dust-born infection could similarly reduce; Krueger and Reed (1976) observe that such protection against bacterial infection could accrue by two further mechanisms - negative ions inhibit bacterial proliferation as well as exert a direct cytotoxic effect on these micro-organisms. Similar conclusion may be drawn from the study of Solanki (1987).

Studies (eg. Hawkins, 1981) and anecdotal reports in lay journals have suggested that negative ionization reduces headaches, improves mood, facilitates alertness etc. Relatively little serious work has however addressed the cognitive effects of ionization. The present study therefore sought to assess the cognitive effects of negative ion atmospheric loading in human volunteers.

## MATERIAL AND METHODS

The sample comprised 65 female graduate course students from a single class in a city college ( $n=65$ ), all of whom agreed to participate in the study. The subjects were randomized into "ionized" ( $n=34$ ) and control ( $n=31$ ) groups and were seated for 2 hours in separate, similar rooms measuring roughly 20 x 20 x 14 feet. The ventilation in both rooms was deliberately reduced to the minimum so as to potentially produce an uncomfortable atmosphere of relative negative ion depletion.

Six ionization units were distributed roughly equidistant from each other in each room. In the control group room, these units were dummies and generated no ion discharge; hence, the relative negative ion deficit in the room was preserved. In the "ionized" group room, the unit (invisibly) generated an individual output of over 10 billion negative ions per sec. so as (after accounting for the 30 seconds life of the average ion, the room occupancy which tended to increase absorption and neutralization of the ions, etc.) to produce an average concentration of at least 2000 negative ions per ml of air about double of what is normal in "healthy" air.

The units were installed in both rooms 24 hours before the experiments, in the "ionized" group room, the unit were switched on at the time of installation itself so that there would be no time lag in the achievement of desired ion levels at the start of the experiment.

Testing of the subjects commenced in the 2 rooms simultaneously, starting in the second hour of occupancy; thus, an hour's 'acclimatization' was provided. Testing was conducted by a different (experienced) psychologist in each room; since the instructions were standardized and since these psychologists did not have to rate the subjects' performances, the question of inter-rater reliability was considered to be of little importance. Subjects and psychologists, and the rater who later scored the protocols, were ignorant of the operational status of the installed units, since ionized atmospheres can not be identified as negative or positive ion-dominant by use of the five senses, the experiment was double-blind.

The following tests were administered :

1. Digit symbol substitution tests of the Weschler's Adult Intelligence Scale. as

modified by Moriadas (1989). In this test, a key is provided at the top of the page, which assigns a symbol to each numeral from 0-9. Below, are 5 lines containing 20 randomly ordered numeral in each line, the subject is instructed to fill in the symbol which corresponds to the numeral. The subject's score is the number of numerals successfully 'coded' over 90 secs.

2. Addition test, an unpublished task in regular use in the Department of Psychology in the institution to which the first author belongs, comprising sets of numbers to be added, with 6 two-digits number in each set, the subject's score is the number of correct answers written over three minutes.

3. Visual memory (complex figure) test from the NIMHANS Neuropsychological Battery, as presented by Mariadas (1989). The test is a complex line diagram with meaningful and meaningless insertions, presented on a display card for 10 secs. The subject is subsequently asked to reproduce as much as he can recall of the diagram on a sheet of paper provided. This paper is collected, the diagram is presented again, and the whole process is repeated as before. After a total of 3 such learning trials, the subject is diverted onto other task. Twenty minutes later, the subject is asked to reproduce the figure again, without earlier having been warned about this delayed recall trial that assesses retention or forgetting. This task contains 21 memory units, and the subject's score for each trial is the number of memory units recalled at that trial.

4. Verbal memory (complex passage) test as devised by Mariadas (1989). A meaningful passage made up of 4 long sentences and containing 44 memory units is read out slowly. The subject is then asked to write down as much as he remembers of the passage. The passage is next read out again, and the test proceeds along the lines described above for the visual memory test, with 3 learning and 1 forgetting trials. The

subject's score for each trial is the number of memory units accurately recalled.

5. Ideational fluency test, a task devised for this experiment, requiring the subject to name as many (different kind) round objects as possible over 1 minute, the subject's score is the number of valid ideas.

6. Clerical speed and accuracy test from the Differential Aptitude Test battery (Bennett *et al.*, 1972). The test comprises of a master sheet and a answer sheet. On each are strings of random letters or numbers. In each strings of the master sheet, combination of letters and numbers is underlined. The subject is required to strike off on the string in the answer sheet the underlined number or letter combinations on the corresponding string in the master sheet. The subject's score is the number of items correctly completed over 3 minutes.

In all the tests described above, subjects are encouraged to work with the utmost celerity and efficiency.

## RESULTS

The mean + S.D. age (years) in the 'ionized' and control group was 18.2 + 1.0 and 18.1 + 0.7 respectively - a non-significant difference (independent sample t test).

Performances, and interpretations thereof, on the Digit symbol, Ideational fluency and Speed and accuracy tests are presented in Table 1. Performances on the Visual and Verbal memory tests are presented in Table 2; here, 3 subjects' protocols in the 'ionized' group were selected at random and discarded to balance the sample of 2 groups and hence permit application of the two way repeat measures analysis of variance; the results of this analysis are presented in Table 3 for learning (trials 1-3)

**Table 1 : Mean  $\pm$  S.D. scores on non-memory cognitive tasks in 'ionized' and control groups.**

	Ionized group (n=34)	Control group (n=31)	Significance (*)
Digit symbol Test	61.6 $\pm$ 11.4	53.4 $\pm$ 9.1	p<0.0025
Addition Test	8.8 $\pm$ 3.3	6.9 $\pm$ 2.2	p<0.01
Ideational Fluency Test	14.3 $\pm$ 4.8	14.3 $\pm$ 3.8	N.S.
Speed and Accuracy test	69.8 $\pm$ 13.0	65.6 $\pm$ 7.4	N.S.

\* Independent sample t test with modified degrees of freedom (to correct for heterogeneity in variances) wherever indicated.

**Table 2 : Mean  $\pm$  S.D. P memory score on visual and verbal tasks in 'ionized' and control groups\* across trial 1-4.**

	Visual memory		Verbal memory	
	Ionized group	Control group	Ionized group	Control group
Trial 1	15.0 $\pm$ 3.5	10.5 $\pm$ 2.6	19.9 $\pm$ 6.9	15.1 $\pm$ 5.0
Trial 2	18.1 $\pm$ 2.5	16.3 $\pm$ 3.4	32.1 $\pm$ 5.5	26.3 $\pm$ 5.5
Trial 3	19.2 $\pm$ 2.2	18.0 $\pm$ 3.1	37.9 $\pm$ 5.3	32.4 $\pm$ 6.1
Trial 4	19.6 $\pm$ 1.6	18.4 $\pm$ 2.7	37.0 $\pm$ 5.8	30.5 $\pm$ 5.4

\* n = 31 in each group

**Table 3 : Results of the 2 way repeat measures ANOVA for learning and forgetting paradigms on the visual and verbal memory tasks.**

	Learning		Forgetting	
	Visual	Verbal	Visual	Verbal
Main effect (groups)	p<0.0005	p<0.0005	p=0.07	p<0.0001
Main effect (trials)	p<0.0001	p<0.0001	p<0.0025	p<0.001
Group x Trials interaction	p<0.0001	N.S.	N.S.	N.S.

and forgetting (trials 3-4) paradigms respectively.

Statistical inferences were based on two-sided hypotheses.

## DISCUSSION

King (1979), in discussing methodological precautions to be observed in ionization studies, stressed (for example) that

subjects should (by use of appropriate electrodes and leads) be held at ground potential to preclude development of strong surface charges that repel approaching air ions. In the present study, such precautions were deliberately dispensed with - while it is important from the scientific point of view to ascertain biological effects to physiological modulators under idealized conditions, it is important for the practical point of view to ascertain whether such physiological modulators exert meaningful, responsible effects under practical circumstances. The latter was a specific objective of this study for, in an air-conditioned room, a crowded office, a computer centre etc. (all situations in which ionizer application has been recommended) 'precautions' such as keeping all occupants of the room at ground potential by appropriate wiring can never be observed!

The Speed and accuracy test tapped attention and concentration; in addition to these two cognitive attributes, the remaining tests evaluated creative speed of thought (Ideational fluency test), arithmetical speed and accuracy (Additions test), scanning and perceptuomotor speed (Digit symbol substitution test) and memory (Visual and Verbal memory tests).

Ideational fluency did not differ between the 2 groups. Rather than interpret this as a lack of effect of negative ions on creative thought, it is suggested that the test was not sensitive to group differences because of either ceiling or floor effect (it is difficult to say which because of lack of experiences with the test) as a function of task nature (naming round object categories) or time frame of testing (1 minute). The most conservative conclusion, therefore, is that this test requires standardization before future application.

Although the speed and accuracy test revealed an advantage for the ionized group, the differences did not reach statistical significance. Therefore, either negative ions do not improve specifically attention and concentra-

tion, or this test is insensitive to negative ion effects. As above, the later explanation is favoured.

Test insensitivity was considered to explain negative findings chiefly because all the remaining tests revealed a striking advantage for the 'ionized' group, ranging from about 15% (Digit symbol test) to over 40% (Visual memory, trial 1).

A special explanation is given here for the result of the memory tests. The significant main effect for groups in both tasks in the learning paradigm indicated the overall superiority of learning in the 'ionized' group. The significant main effect for trials indicated meaningful learning in both groups across trials. The significant group trials interaction in the visual memory task underscored the faster learning in the control group, this is actually because of a ceiling effect in the 'ionized' group, the mean score in which trial 3 (19.2) approximate the maximum score possible (21) in the task. This artefact did not cloud results in the verbal memory task as group means on all trial in both groups were well below the maximum score possible (44), the non-significant interaction thus indicated comparable rates of learning in the 2 groups.

The forgetting paradigm in the memory tasks sought to assess whether there was any difference in change of scores across 'ionized' and control group between trial 3 and 4. The absence of significant group x time interaction (the main effects for group and time not being relevant to the hypothesis under consideration) was not significant in both memory tasks, indicating that negative ions did not influence retention of learnt material.

In synthesis, therefore, negative ions were found to significantly benefit a variety of cognitive functions across several tests. The findings of this study are in support of recent research documenting similar benefit in nor-

mal as well as in impaired populations (Hawkins and Barker, 1978; Morton and Kershner, 1984; Baron, 1987). Of special note is that this study documents beneficial effects despite deliberate non-observance of precautions observed in other positive-finding studies. This is an important point as such precautions (discussed earlier) are not practical in the various situations in which negative ionization of the atmosphere may be useful.

The mechanism whereby negative ion facilitate cognitive functioning is at present obscure. One specific mechanism documented is an anti-serotonergic effect of negative ions (Krueger and Reed, 1976) which can benefit certain anxiety states that result from serotonergic irritation (Giannini *et al.*, 1983 and 1986). To the extent that serotonin-irritation anxiety is reduced, cognitive performance may logically be expected to improve. However it is unclear how such a mechanism may be extrapolated to normal volunteers in a test atmosphere, unless one hypothesizes that the test atmosphere, by virtue of negative ion depletion / relative positive ion surfeit, produced serotonergic irritation (irrespective of presence or absence of manifest anxiety) in the control group, which effect was neutralized in the 'ionized' group. This hypothesis unfortunately could not be tested due to unavailability of instrumentation for measuring degree of atmospheric ionization during the study, and because assessment of serotonergic parameters (e.g. in serum and urine) had not been considered at the time of planning the study. It is interesting to note that the 'restful' effect of negative ions has been reported in manic patients too (Misiasek *et al.*, 1987).

In conclusion, This study suggests that negative ions may benefit cognitive functioning, and may therefore find application in practical situation in which there is a negative ion deficit; it is reassuring to note that, at least in the limited work that had so far been conducted, negative ions exert no harmful effect even following

protected exposure (Sulman *et al.*, 1978). Negative ions however need to be researched further before the practical applications are dogmatically asserted, lest the field fall into desrepute as it did, briefly, earlier (Krueger and Reed, 1976).

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